Game of Missuggestions
Semantic Analysis of Search-Autocomplete Manipulations

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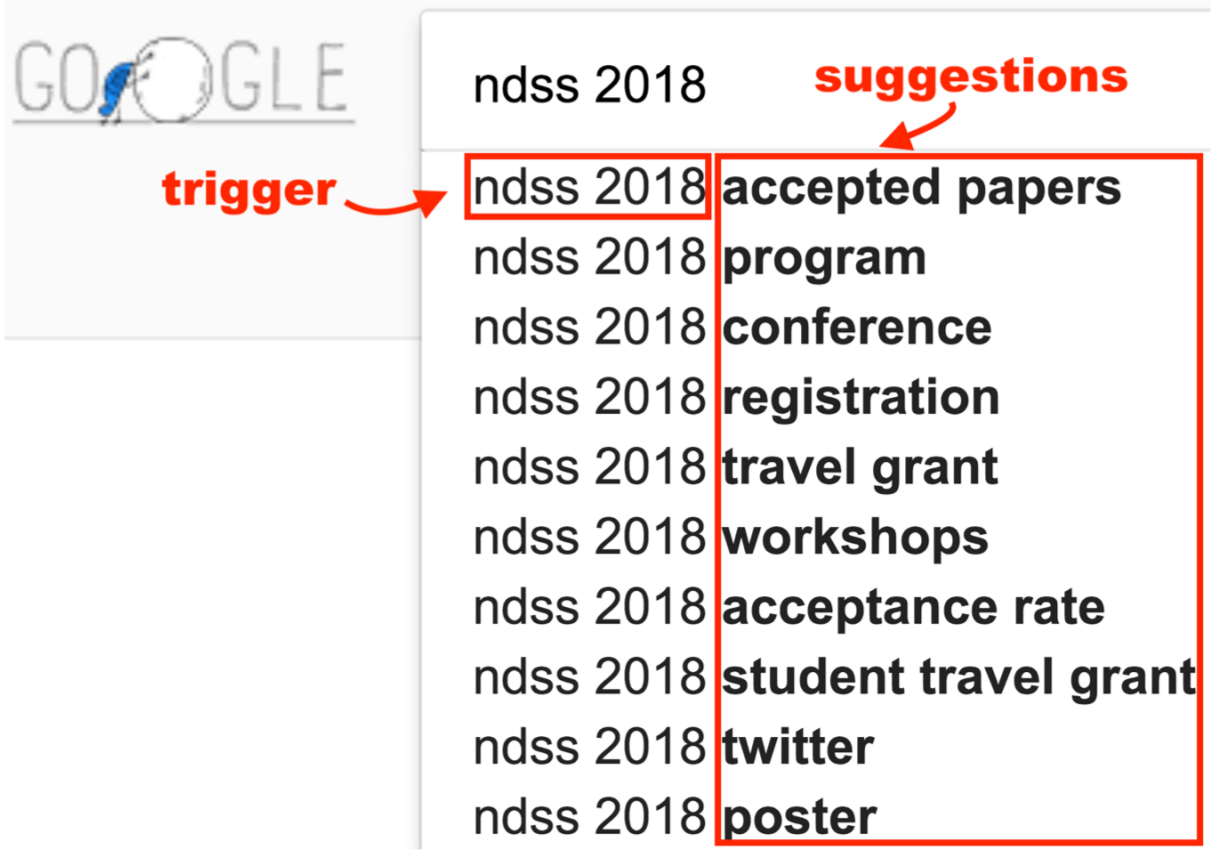
Indiana University Bloomington[1]

William and Mary[2]

Georgia Institute of Technology[3]

Autocomplete



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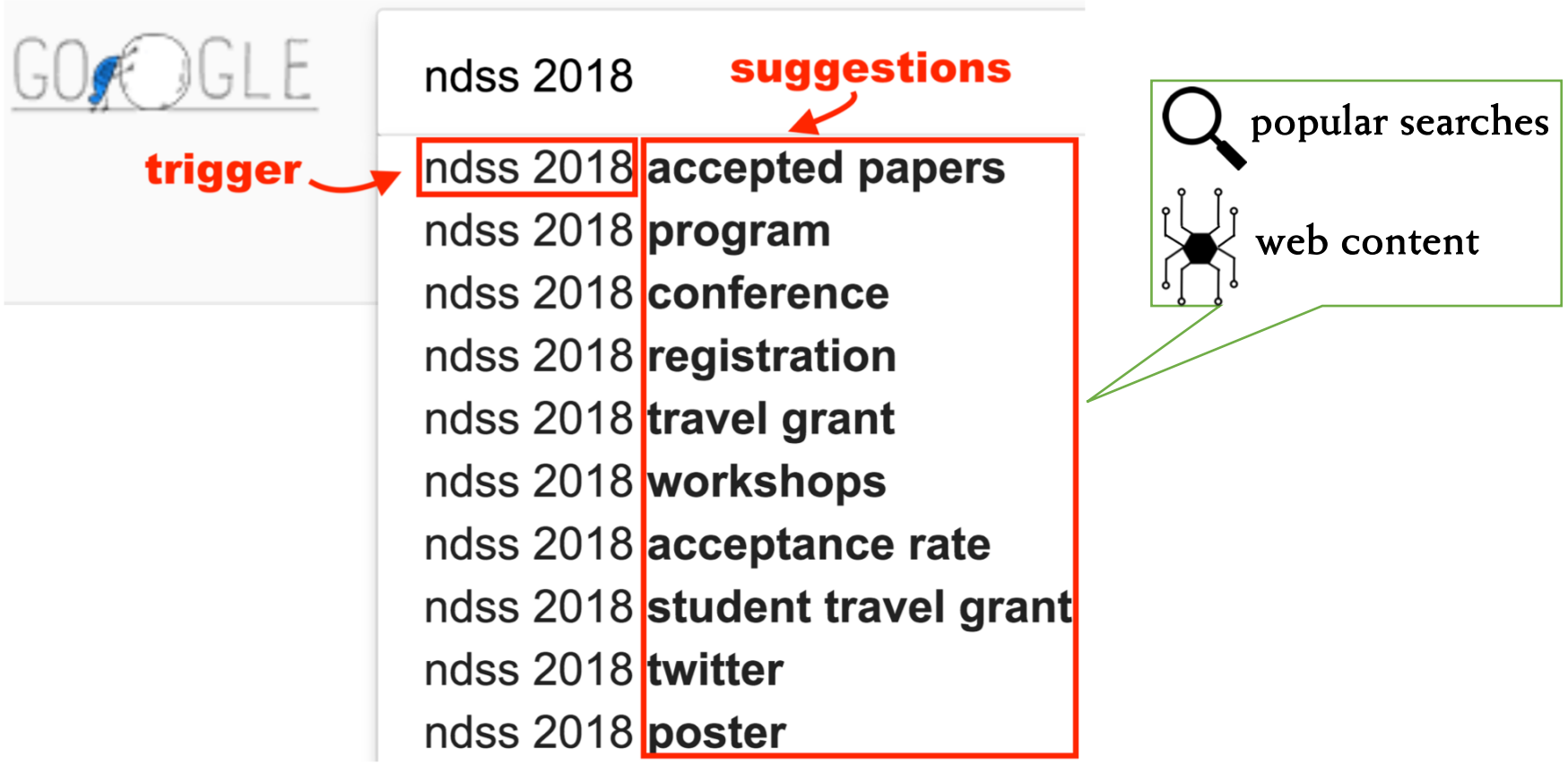
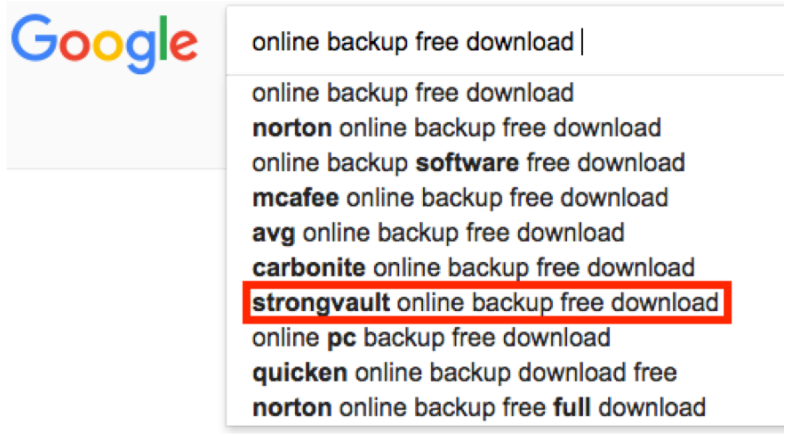
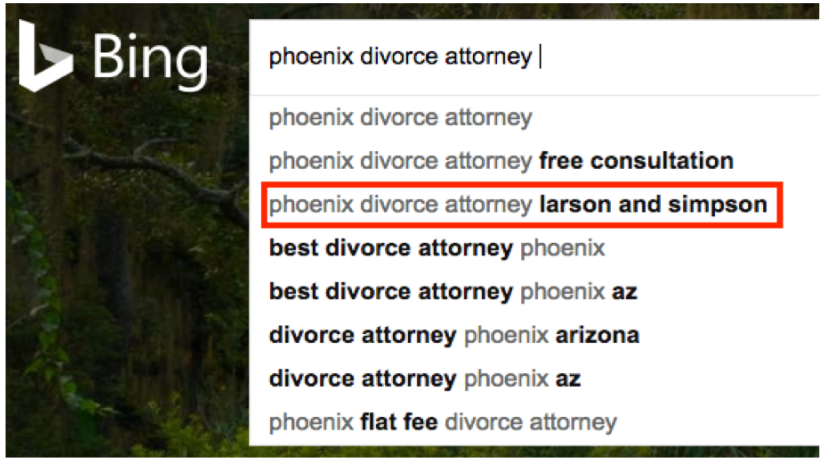
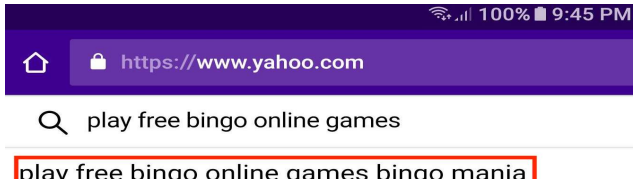


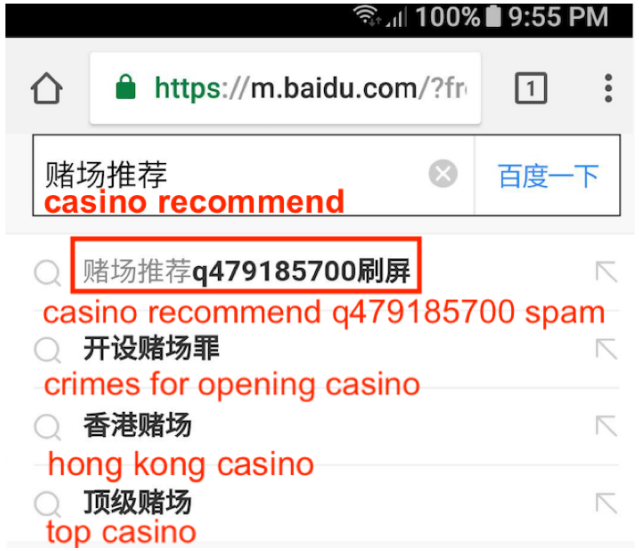
How predictions are made
https://support.google.com/websearch/answer/106230

Winter is here









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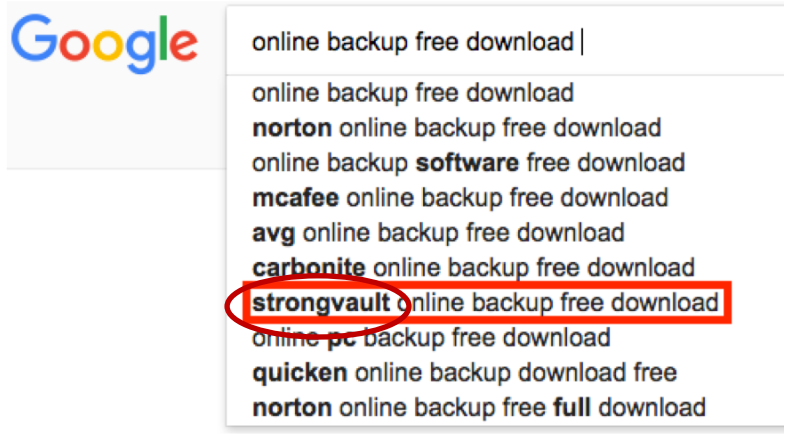
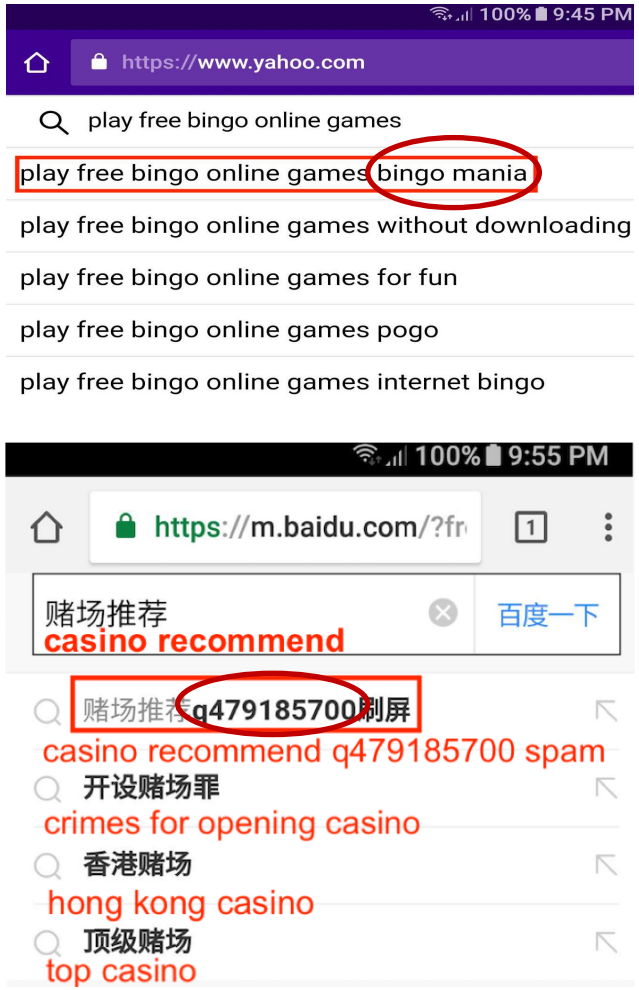
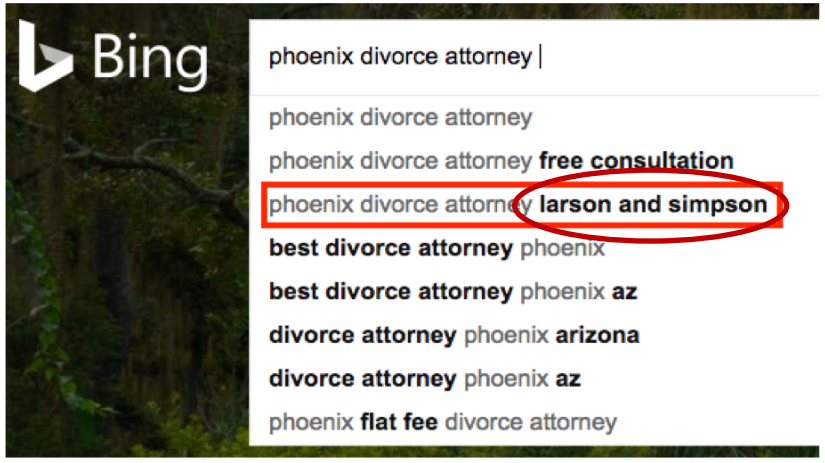


promotion target





GAME OF MISSUGGESTIONS

Autocomplete Manipulation

pollute search logs

Service Provider	Country	Supported Platforms	Cost	Time
Affordable Reputation Management	USA	Google, Bing, Yahoo!, Amazon etc.	$370 / m	1 - 3 months
Search Reputation	USA	Google, Bing, Yahoo!	$1,200 / m	3 months
Google Autocomplete Changer	USA	Google, Bing, Yahoo!	$2,500 (fixed)	3 months
Seopmb	China	Baidu, Sogou, 360	$1 ~$20 / d	1 month
iXiala	China	Baidu, Sogou, 360, Taobao etc.	$2 ~$12 / d	3 - 15 days

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pollute web content

compromised websites

spam hosting webpages

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Challenges

- Search log analysis
  can only be done by search providers

- Web content analysis
  a thorough study is non-trivial on massive data

Little understanding about the real-world impacts of illicit promotions

Sacabuche

Search AutoComplete Abuse Checking

- **first** detection system **without** accessing to search logs
- **novel NLP techniques** achieves highly efficient, accurate and scalable
- **first large-scale analysis** of autocomplete missuggestions
- **first step** to understand the ecosystem of this underground business

Observation

- Semantic inconsistency

  trigger: online backup free download

  legitimate: ✓ online backup **software** free download

  manipulated: ✗ **strongvault** online backup free download

Observation

- Semantic inconsistency

trigger: online backup free download

semSim=0.96

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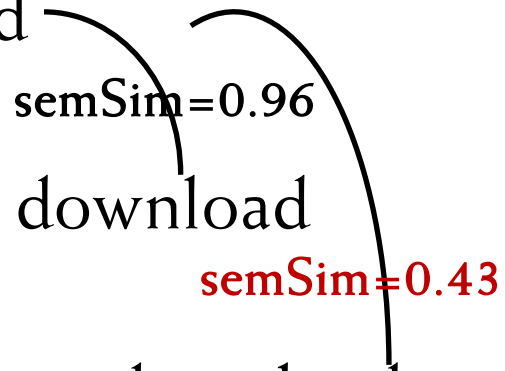


legitimate: ✓ online backup **software** free download

manipulated: ✗ **strongvault** online backup free download

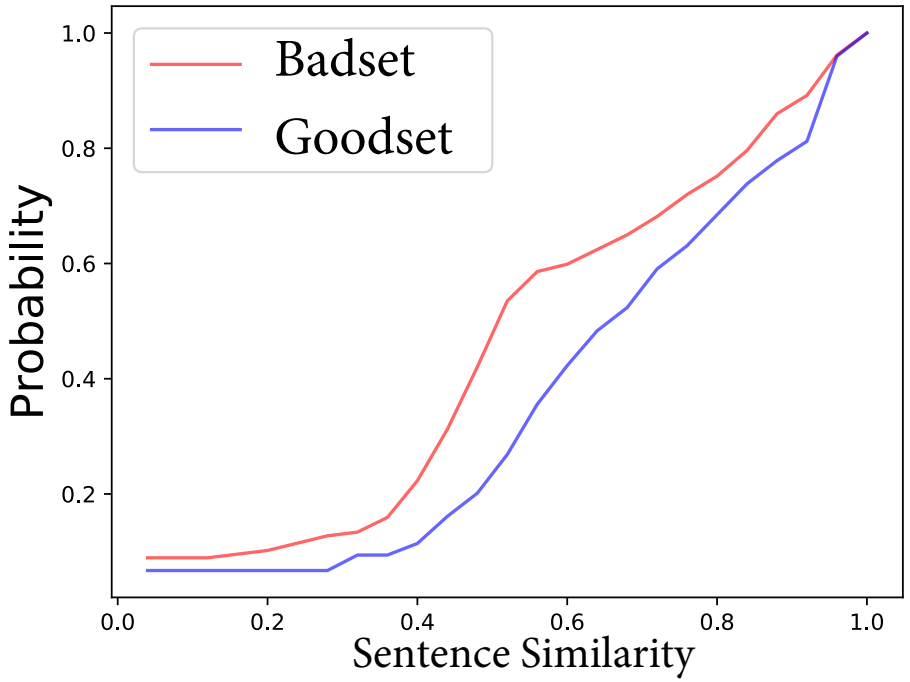
Sentence Similarity

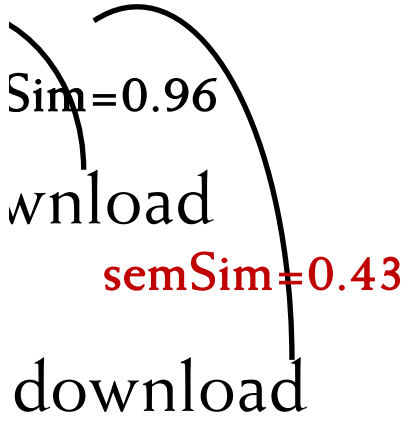
- Semantic inconsistency

  trigger:

  legitimate:

  manipulated:





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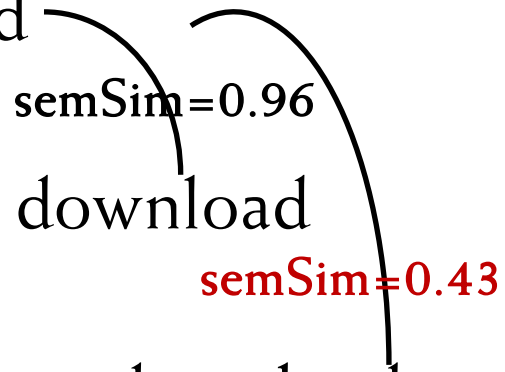

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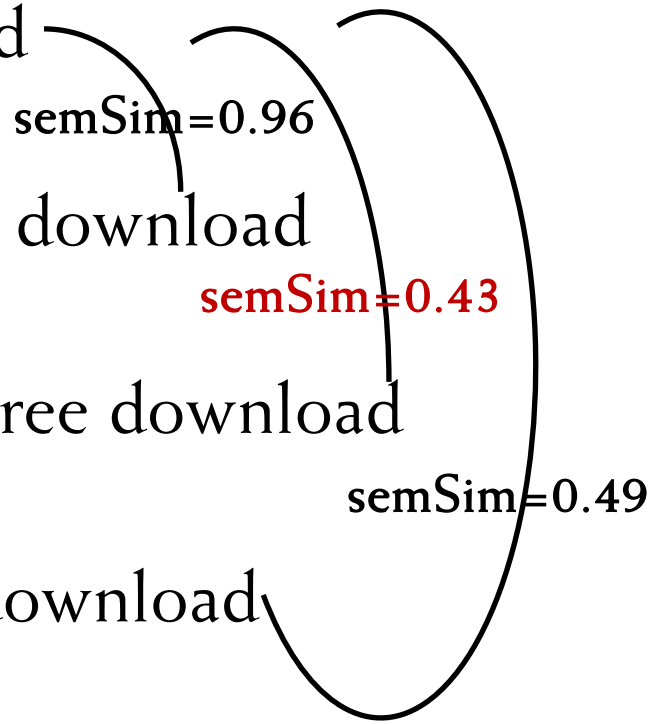

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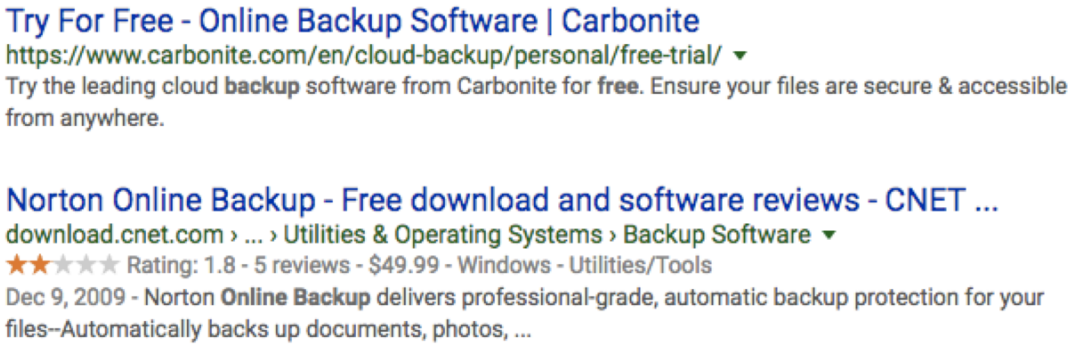
- Search results inconsistency



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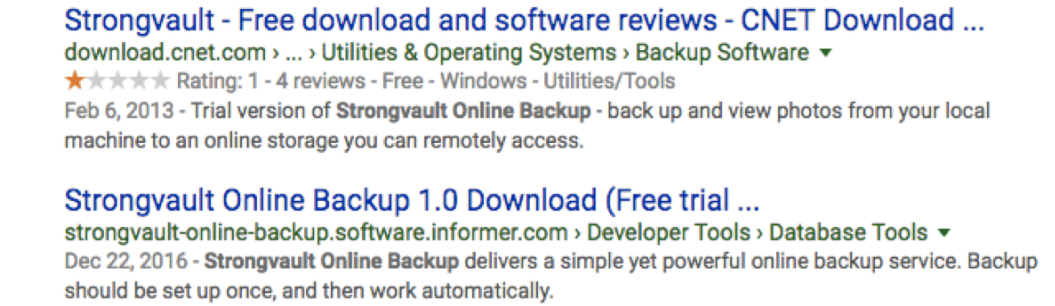
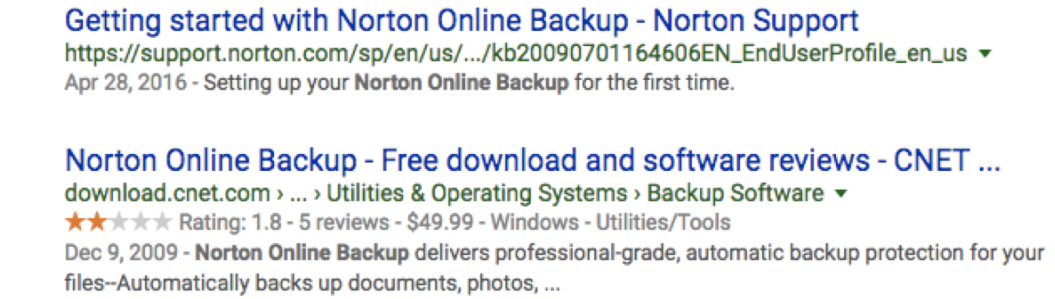


missuggestion: **stongvault** online backup free download



suggestion: **norton** online backup free download

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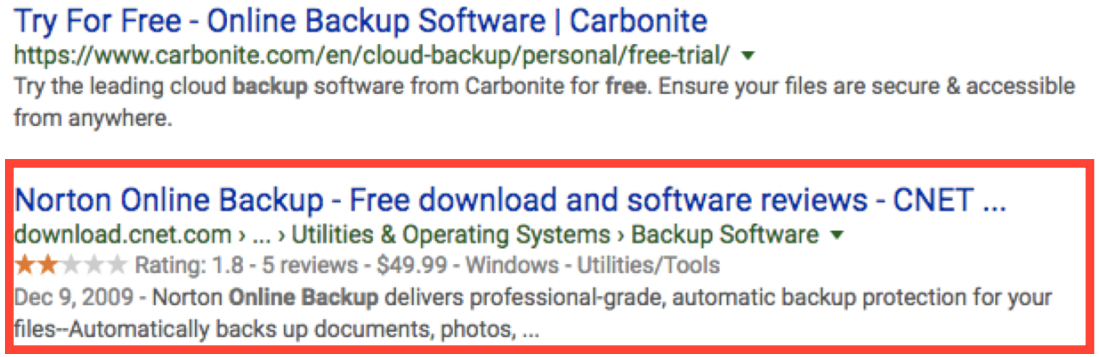

trigger: online backup free download

missuggestion: **stongvault** online backup free download

suggestion: **norton** online backup free download

Search Results Similarity

- Search results inconsistency

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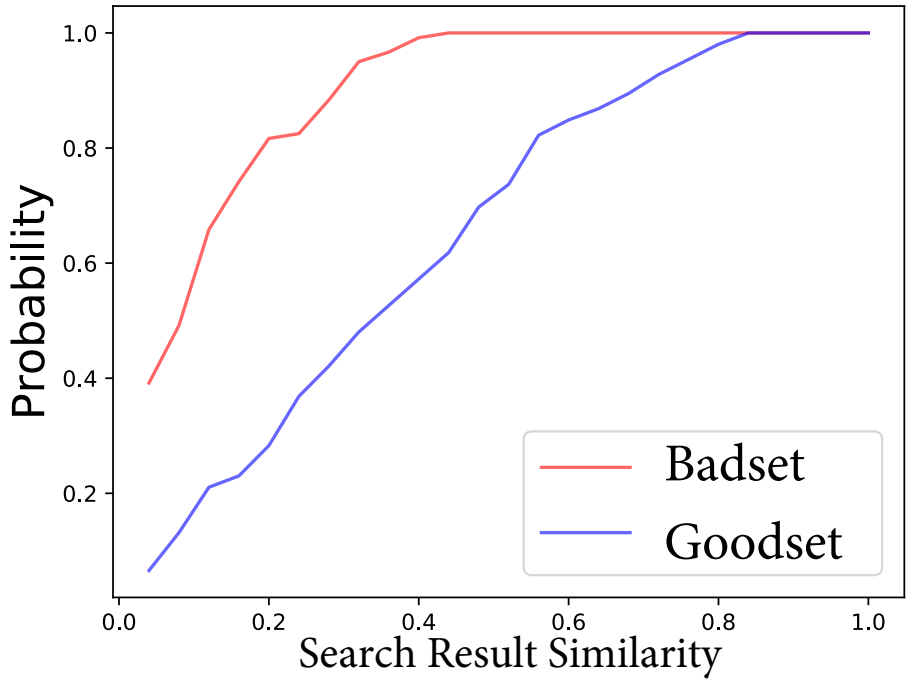

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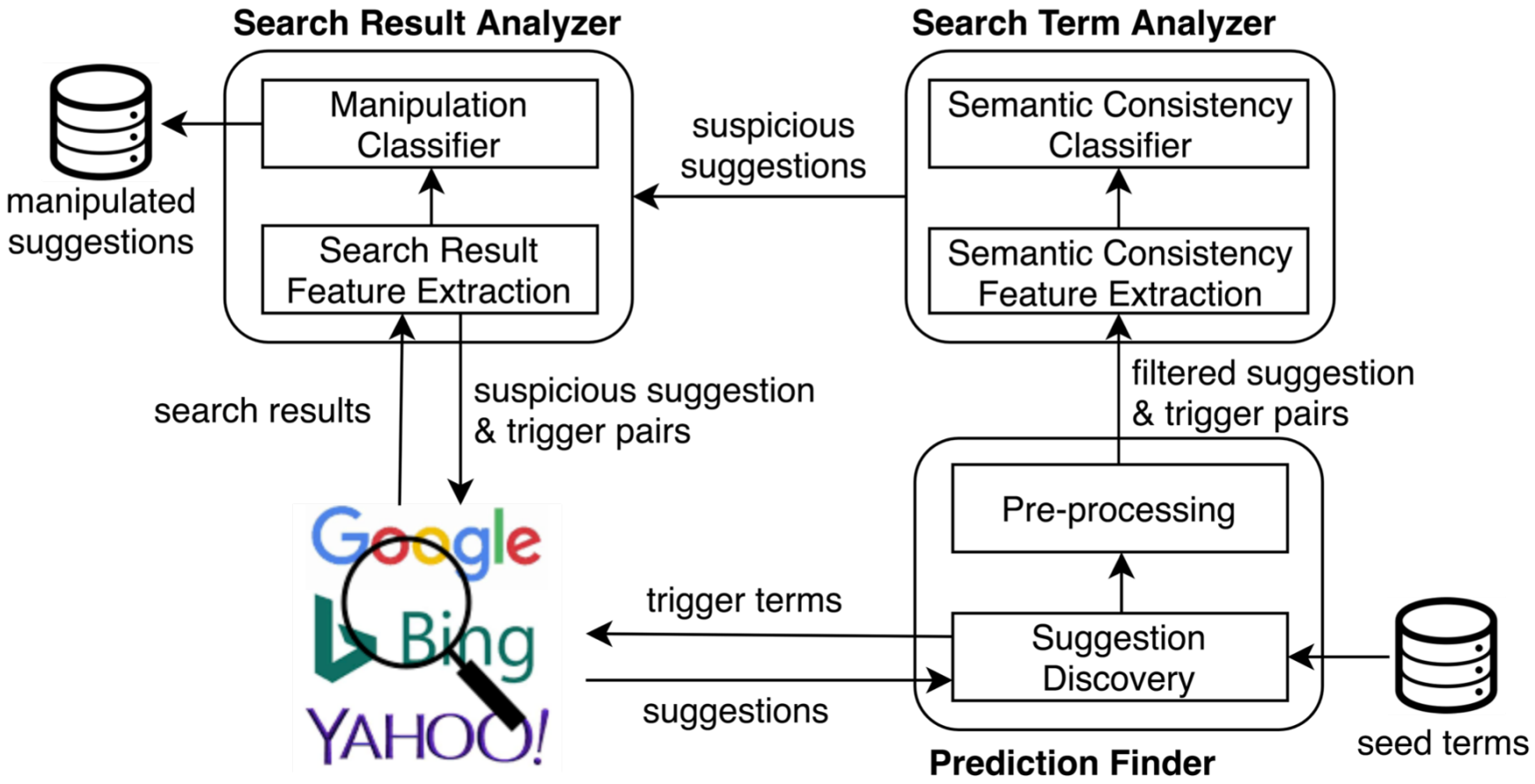
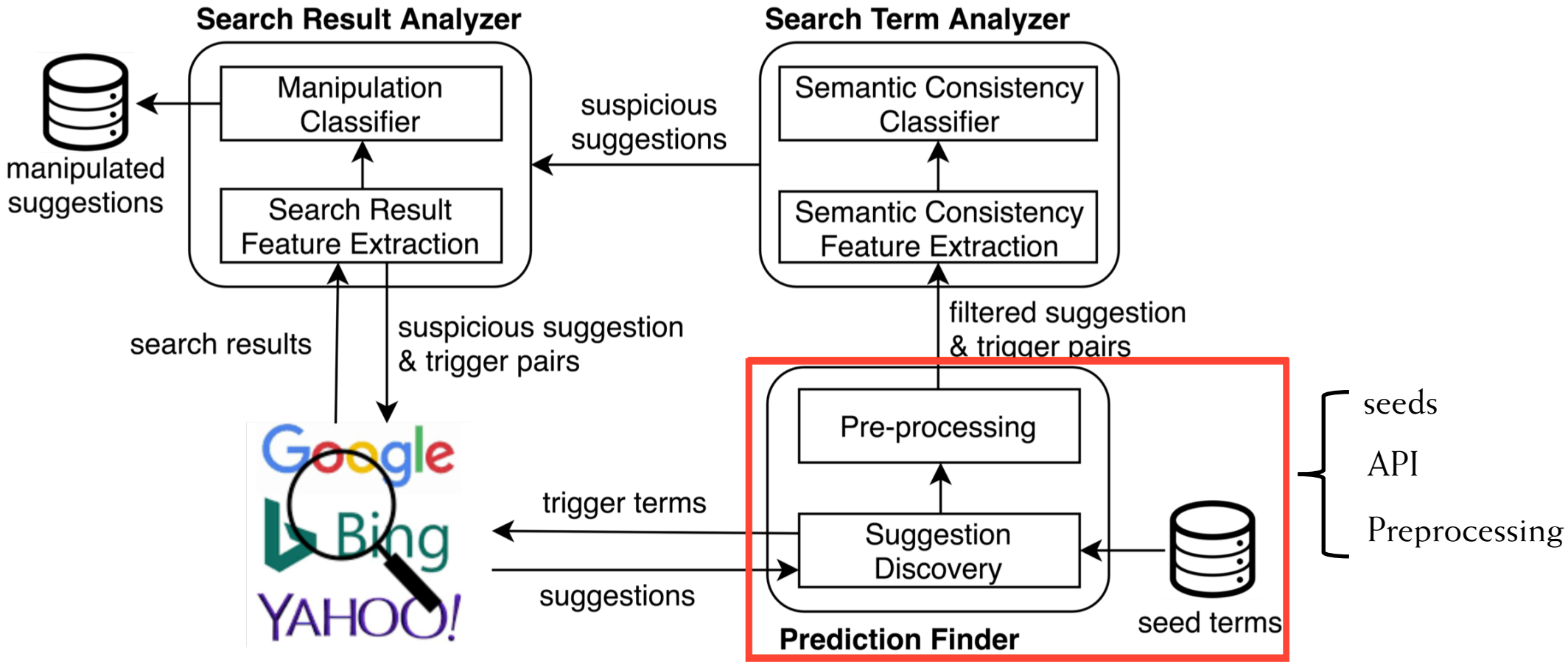
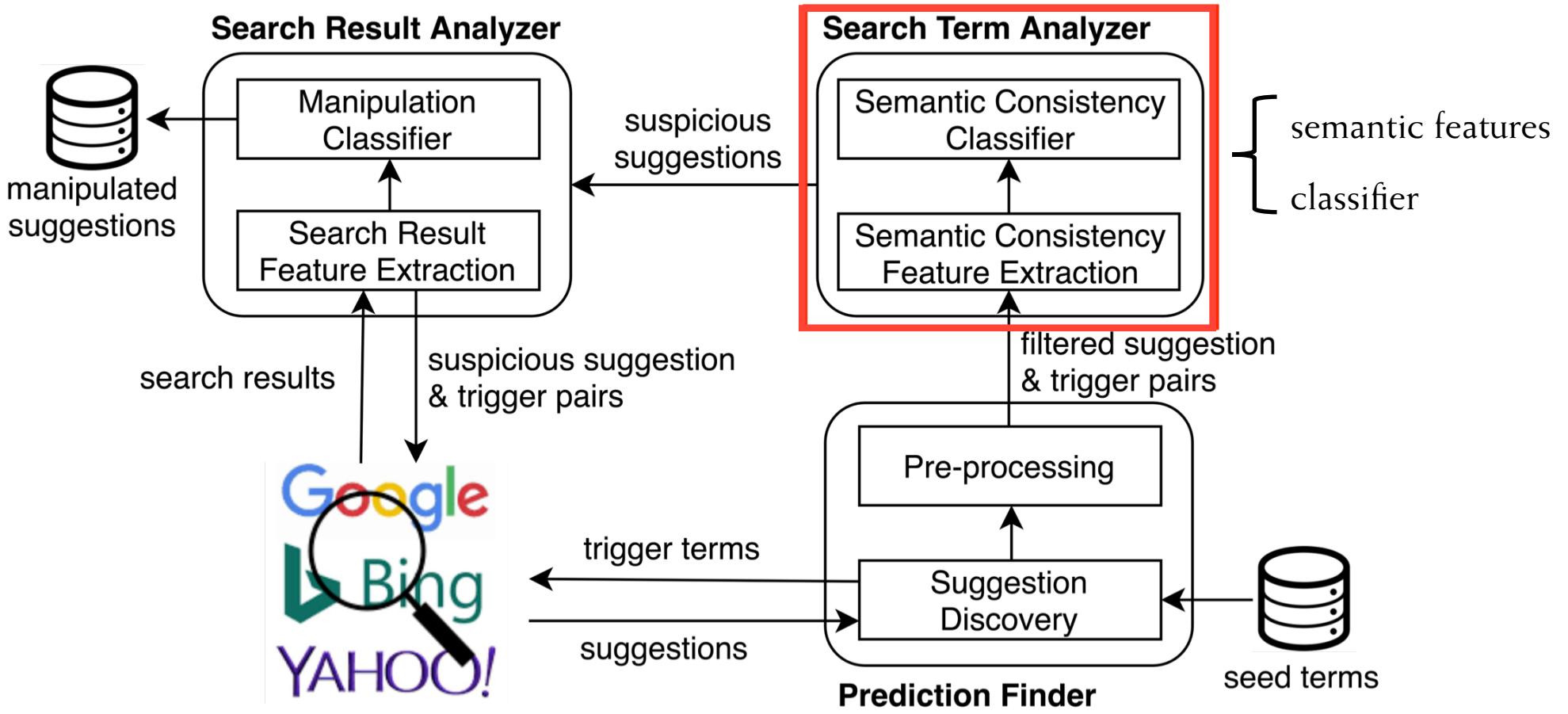
Architecture



Prediction Finder



Search Term Analyzer



Semantic Feature example

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- Sentence level similarity

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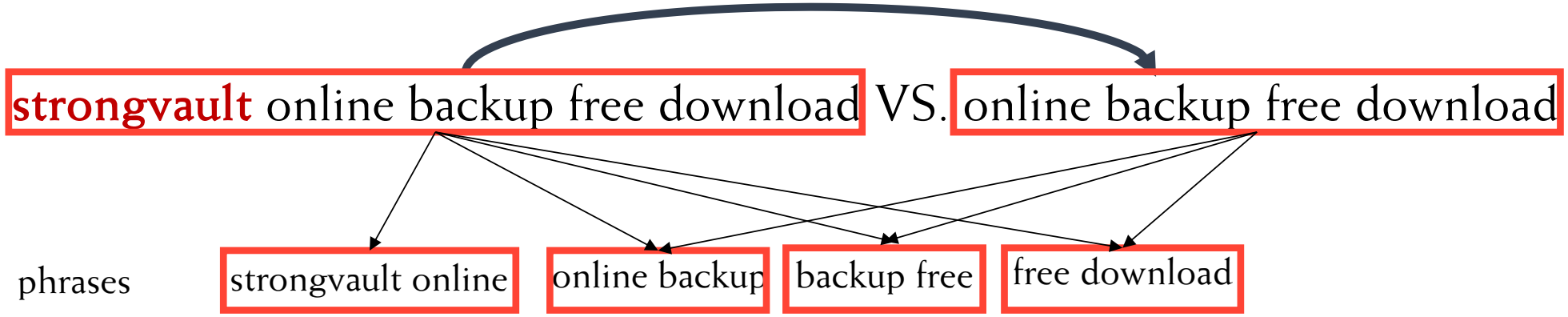

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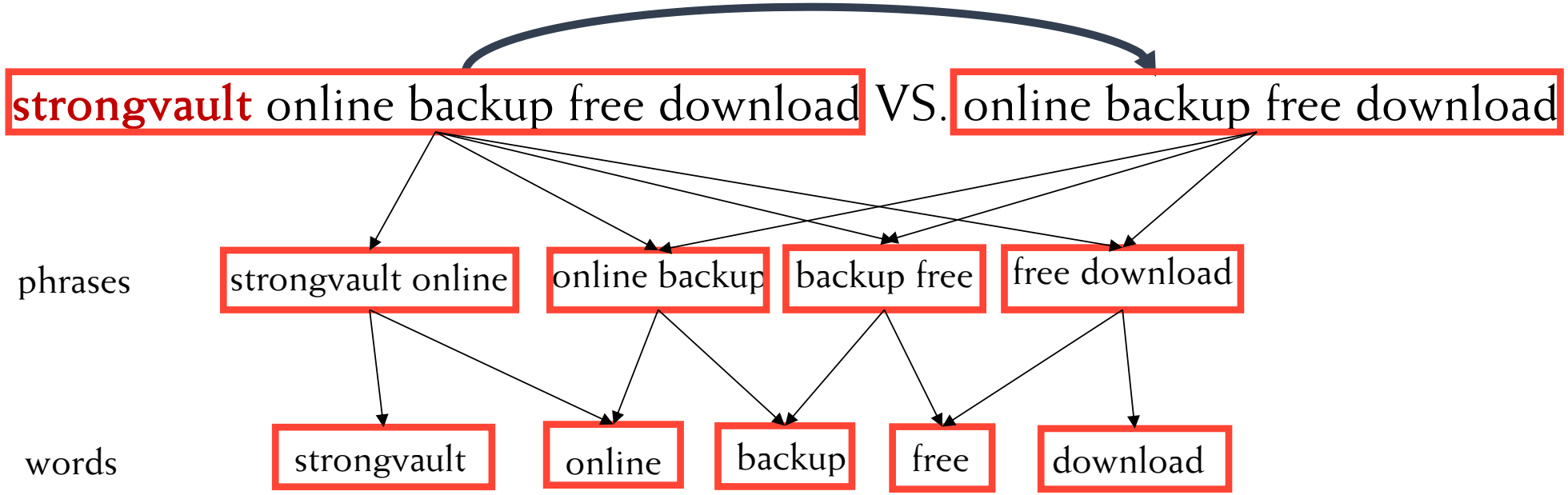

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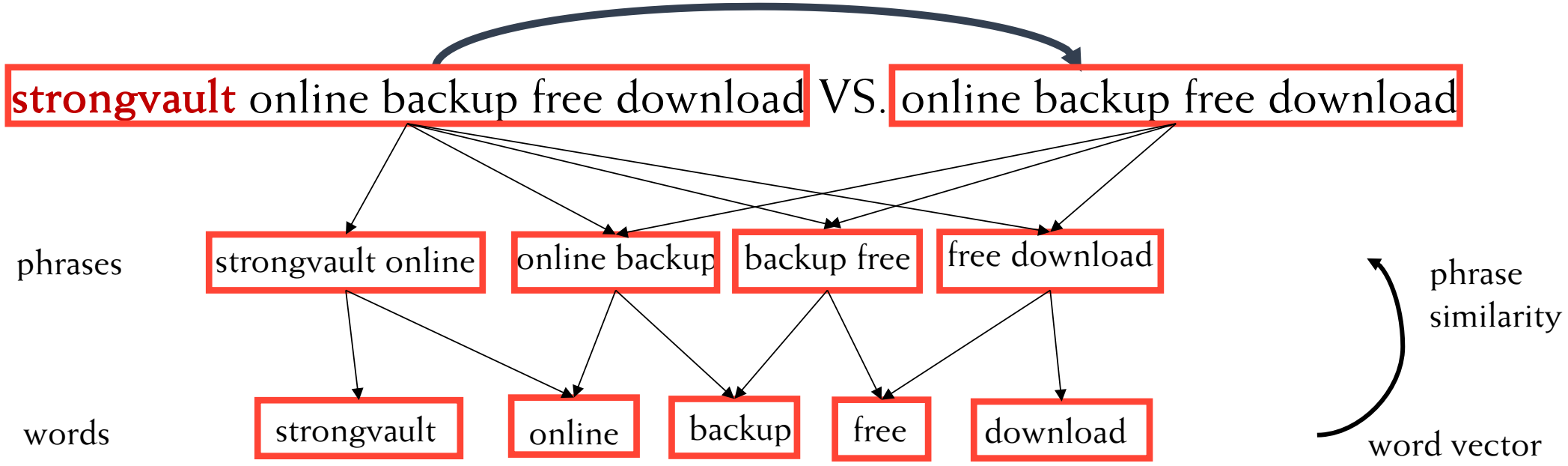

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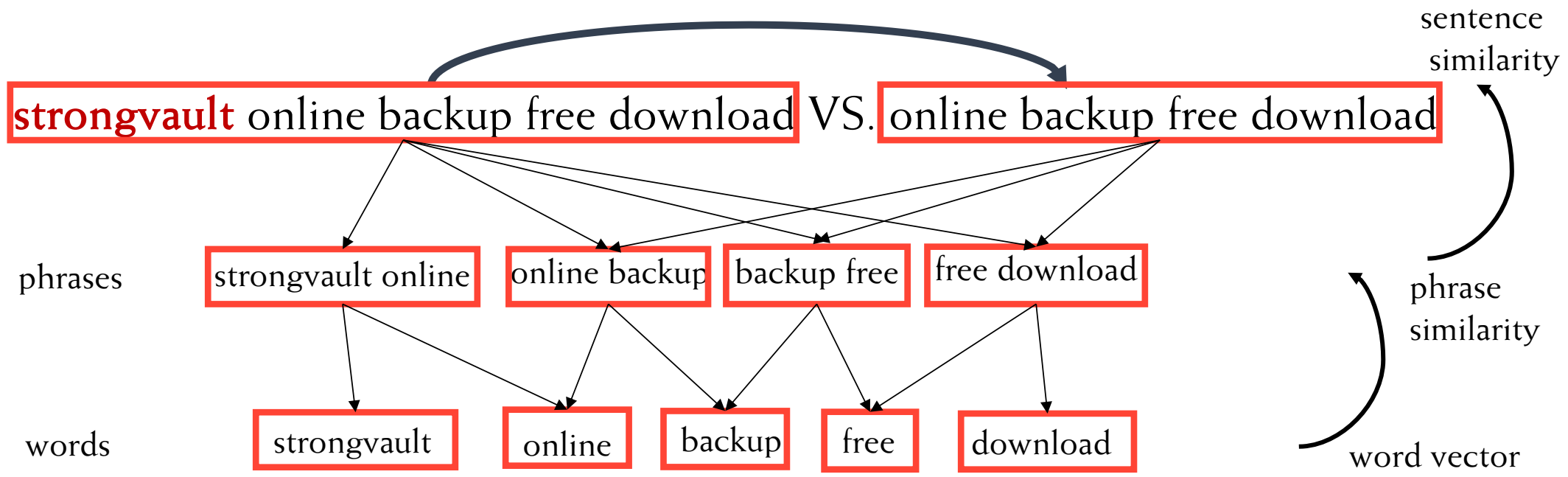


Semantic Features

- Sentence similarity

$$F_{ss}(s^a, s^t) = \frac{SK(s^a, s^t)}{\sqrt{SK(s^a, s^a)SK(s^t, s^t)}}, \qquad SK(s^a, s^t) = \sum \lambda^2 PK(p^a, p^t)$$

$$PK(p^a, p^t) = \prod_{i=1}^{len} WK\left(w_i^a, w_i^t\right), \qquad WK\left(w^i, w^j\right) = \left[\frac{1}{2}(1 + \cos Sim(w_i, w_j))\right]^{\alpha}$$

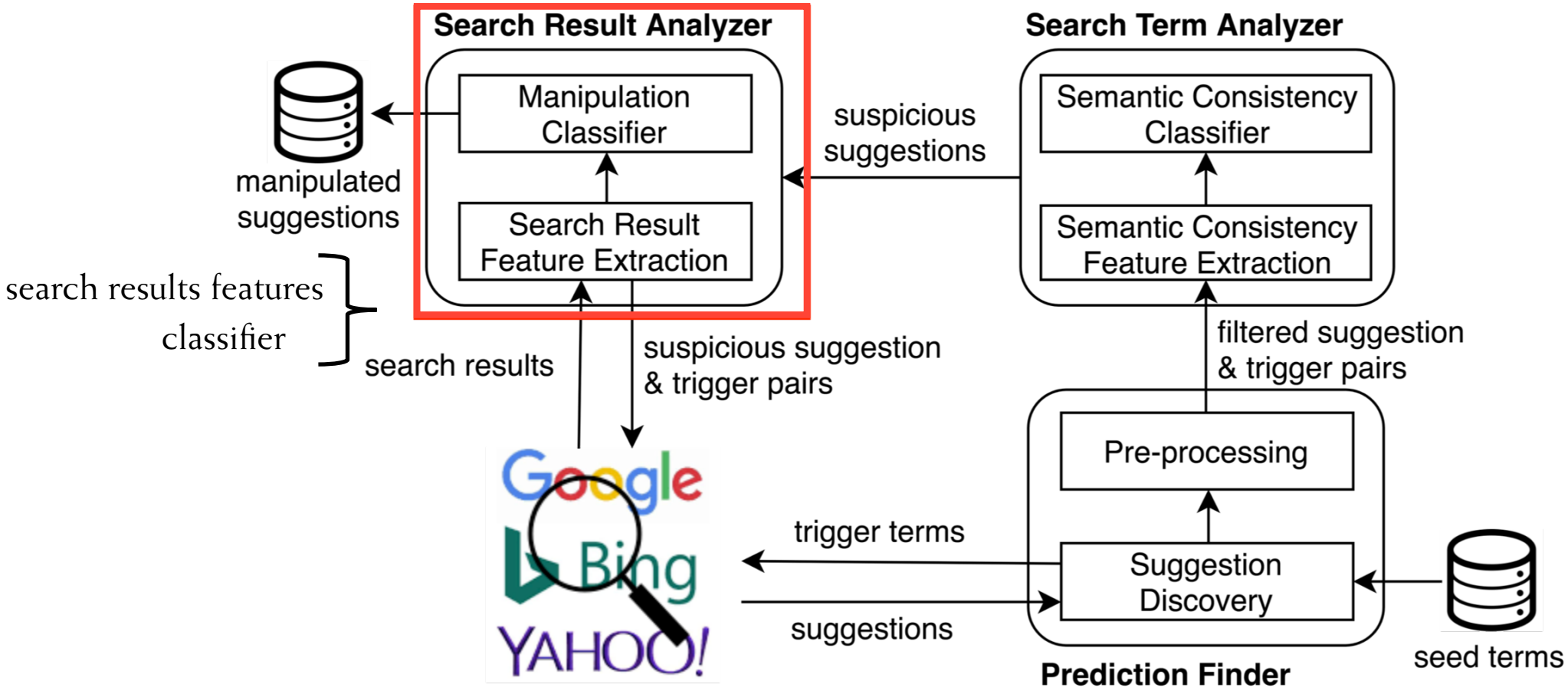
- Word similarity

$$F_{ws}(w^a, w^t) = MAX(AVG_j\left(WK\left(w_i^a, W_j^i\right)\right))$$

- Infrequency

$$F_{if}(w^a, w^t) = \frac{MAX_j(9 - log_{10}Freq\left(w_j^t\right))}{MAX_i(9 - log_{10}Freq\left(w_i^a\right))}$$

Search Result Analyzer



Search Result Features

- Result similarity

  $F_{rs}(D^a, D^t) = (1-p)\sum_{d=1}^{\infty} p^{d-1} A\,(D^t, D^a)^d$

- Content impact

  $F_{ci}(w^a, H^a, H^t) = \ MIN_i(R(w^a, H^a, H^t))$

- Result popularity

  $F_{\mathrm{rp}}(D^a, D^t) = RBO(AP^a(D^a), AP^t(D^t))$

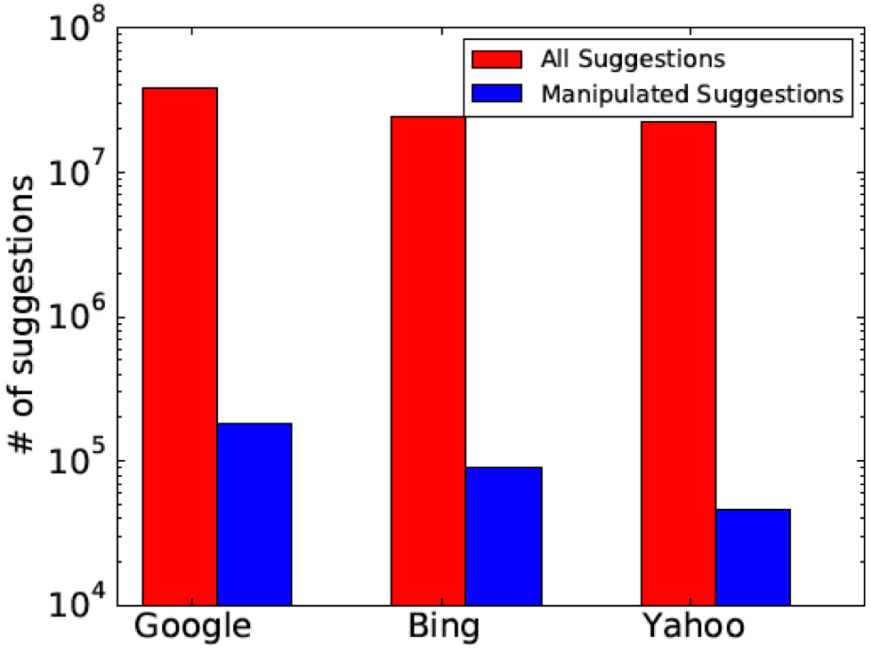
- Result size

  $F_{rs}(N^a, N^t) = \dfrac{N^a - N^t}{N^t}$

Evaluation

- Datasets
  - Badset: 150 missuggestions, 296 result pages
  - Goodset: 300 legitimate suggestions, 593 result pages
  - Unknown set: 114 millions trigger-suggestion pairs, 1.6 millions result pages
- Accuracy and coverage
  - Ground truth: precision 96.23%, recall 95.63%
  - Unknown set: precision 95.4% on 1K suspicious trigger-suggestion pairs
- Performance
  - 1.5s / trigger-suggestion pair

Scope and magnitude

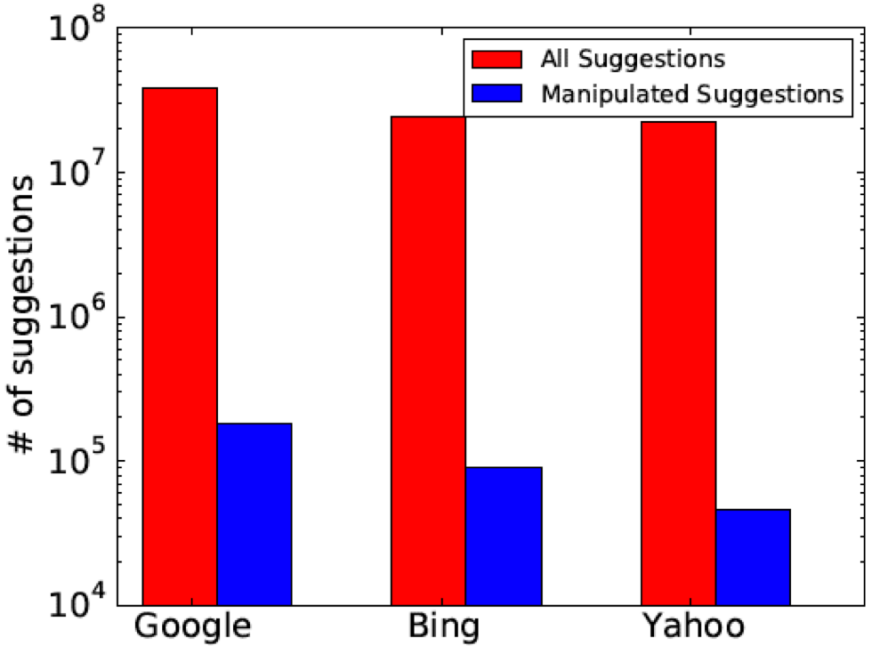


Number of missuggestions on each platform
(G: 0.48%, B: 0.37%, Y: 0.2%)

Trigger Category	# of terms	# of manipulations	Vol-ume
Lending Products	1389	1580/34629	4.13%
Home Services	17059	16712/413836	2.47%
Pharmaceutical	3715	3876/93929	2.09%
Auto Services	3477	3916/92220	1.08%
Technology	29115	32696/762548	0.91%
Education	17311	17628/423352	0.81%
Shopping	30465	32986/773087	0.72%
Gambling	413	454/10314	0.68%
Travel	6434	6554/153842	0.48%
Legal Services	14064	14084/348548	0.55%

Categories of the polluted triggers

Scope and magnitude



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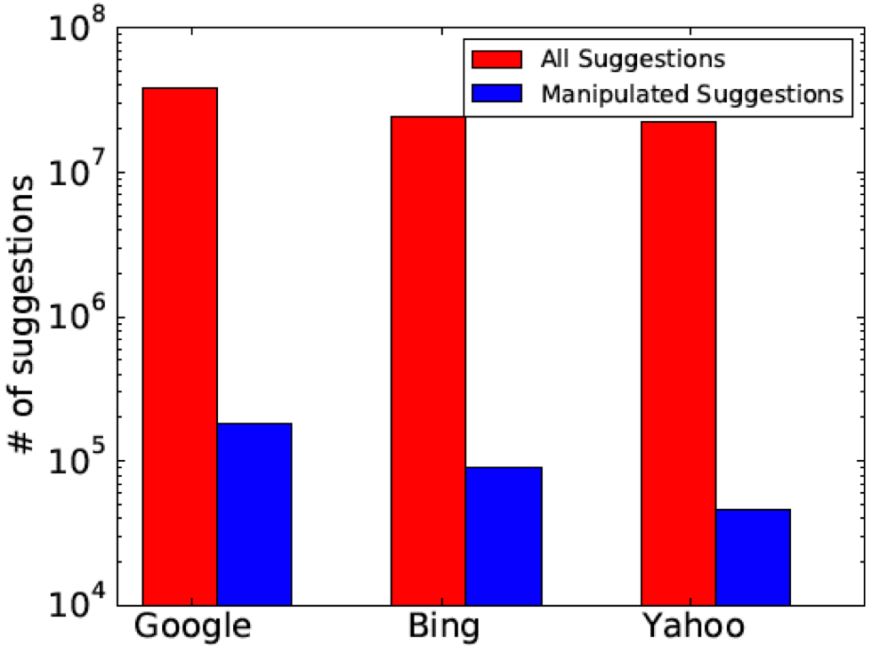

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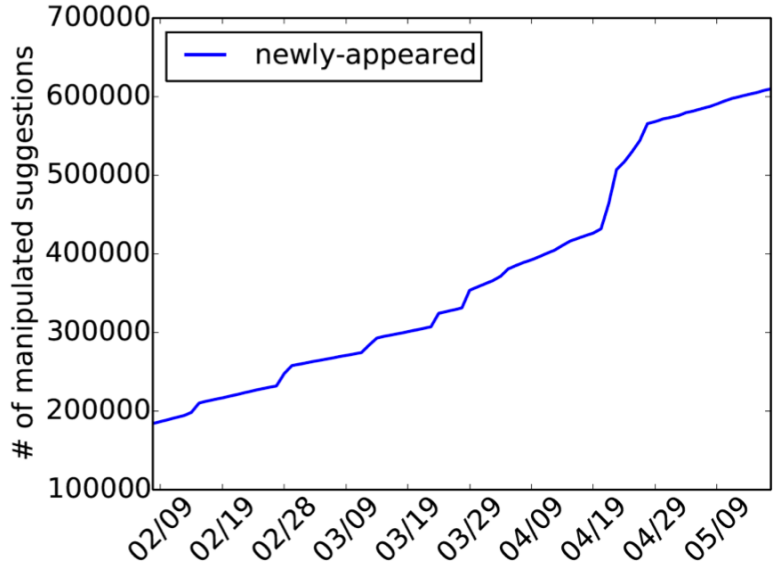
Categories of the polluted triggers

257K polluted triggers

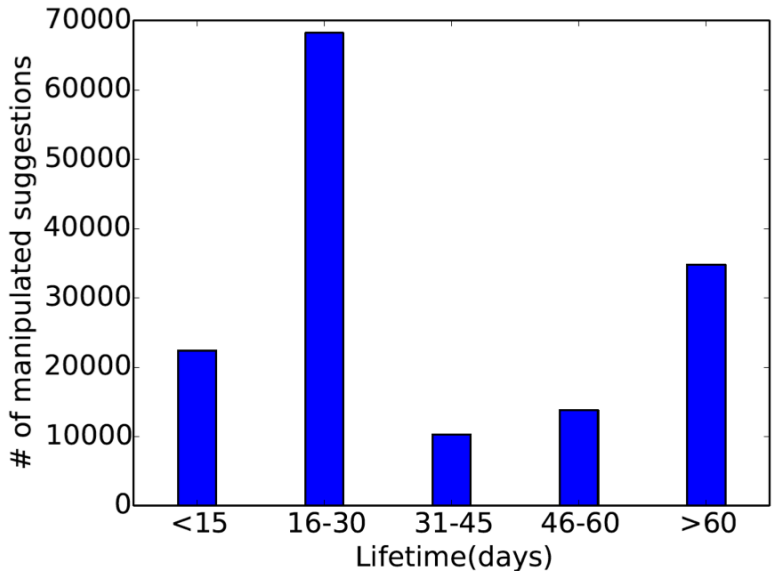
383K missuggestions

Evolution and lifetime



Number of missuggestions over time

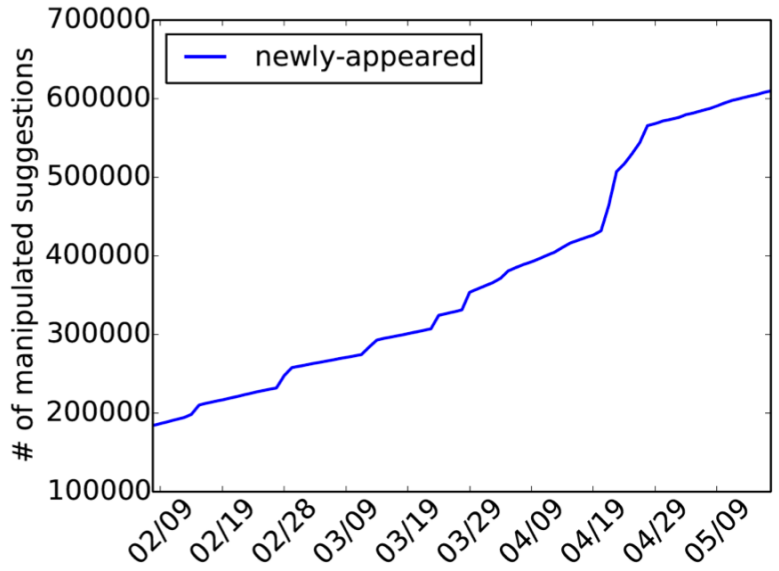
- 71.3% of newly-appeared missuggestions related to newly-appeared polluted triggers
- 1.9% of triggers were polluted on average



Lifetime distribution of missuggestions

- 39.3% of missuggestions stay > 30 days
- 34 days vs. 63 days (missuggestion vs. legit.)

Evolution and lifetime



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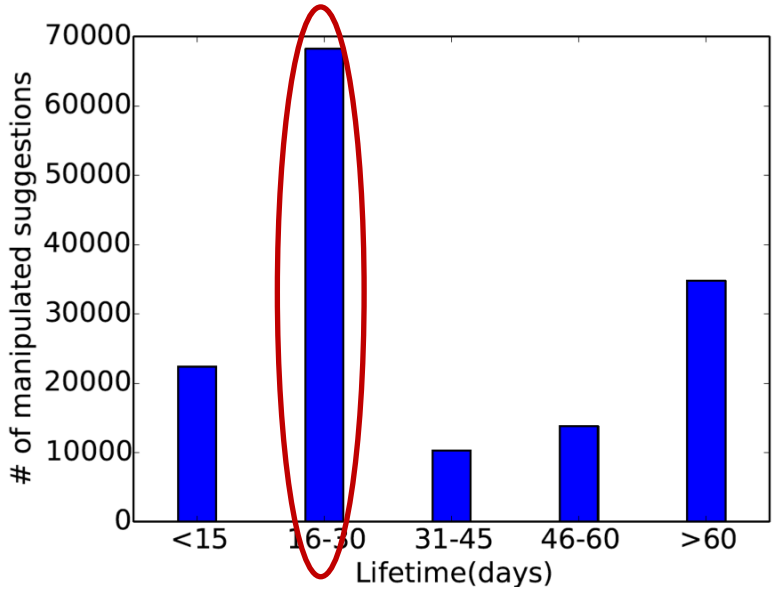
- 1.9% of triggers were polluted on average



Lifetime distribution of missuggestions

- 39.3% of missuggestions stay > 30 days
- 34 days vs. 63 days (missuggestion vs. legit.)

Missuggestion content and pattern

- 20% missuggestions related to more than one trigger

"free web hosting and domain name registration services by doteasy.com" related to 123 triggers

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Pattern	# of missuggestions	Example
trigger relevant content+target	195,738	phoenix divorce attorney sampair
target+trigger relevant content	188,238	strongvault online backup free download
target+" - "+ trigger relevant content	2,278	bd&j - los angeles personal injury lawyers
trigger relevant content+by+URL	1,446	custom t shirt design software and application tool by panaceatek.com
trigger relevant content+from+URL	427	reliable web hosting from webhostinghub.com

Top 5 missuggestion patterns

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Revenue analysis

- Manipulation service provider

  iXiala

  10K sites request suggestion manipulation

  $54K/week commission earned by manipulation operators

  $515K/week for 465K manipulated suggestions

Discussion

- Limitations
  - adversary can make the manipulations mimic benign ones
  - lack of ground truth, manual efforts involved

Discussion

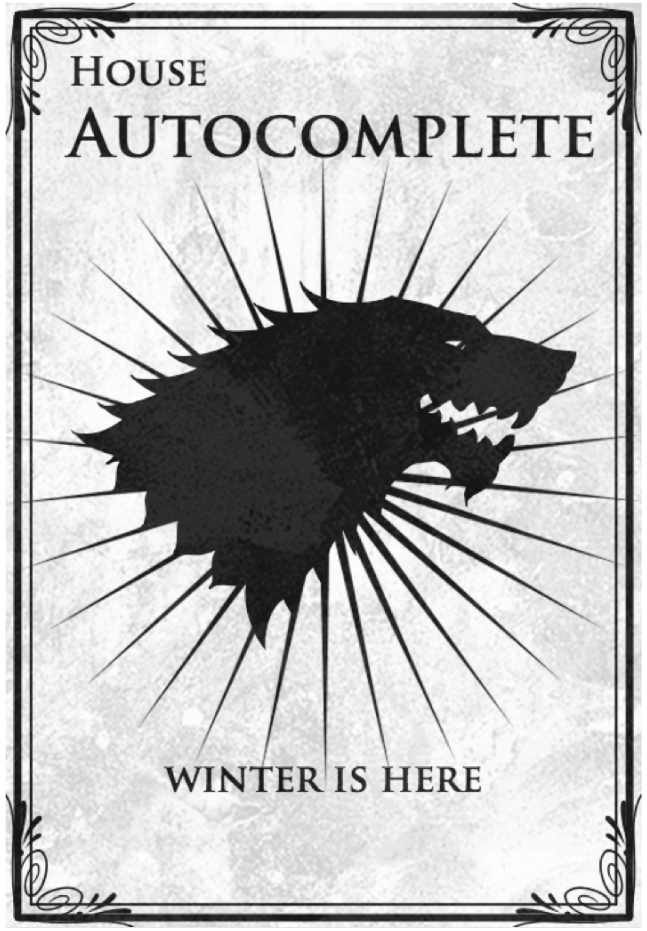
- Limitations
  - adversary can make the manipulations mimic benign ones
  - lack of ground truth, manual efforts involved
- Lesson learned
  - unpopular targets related to triggers
  - similar keyword patterns

Conclusion

- **first large-scale analysis** of autocomplete missuggestions, and make **first step** to understand the underground ecosystem

- **novel NLP techniques** to build up the first detection system **without accessing** to search logs

Questions & Answers



Data collection

- Datasets

Dataset	# of suggestions	# of triggers	# of result pages
Badset	150	145	295
Goodset	300	298	593
Unknown set	114,275,000	1,000,900	1,607,951

- Validation criteria
  - missuggestion must promote a target whose own reputation cannot make itself stand out in the search results of the trigger
  - missuggestion and its search results conflict with the user's original search intention

Semantic Consistency Classifier

- 100 missuggestions + 150 legitimate trigger-suggestion pairs
- SVM classification model with 5-folder cross validation
- Precision 94.59%, Recall 95.89%

Label	Feature	F-score
$F_{ss}(s^a, s^t)$	sentence similarity	0.597
$F_{ws}(w^a, w^t)$	word similarity	0.741
$F_{if}(w^a, w^t)$	infrequency	0.653

Missuggestion Classifier

- 150 missuggestions + 300 legitimate trigger-suggestion pairs
- SVM classification model with 5-folder cross validation
- Precision: 96.23%, Recall 95.63%

Label	Feature	F-score
$F_{rs}(D^a, D^t)$	result similarity	0.782
$F_{ci}(w^a, H^a, H^t)$	content impact	0.808
$F_{\mathrm{rp}}(D^a, D^t)$	result popularity	0.632
$F_{rs}(N^a, N^t)$	result size	0.745

Evaluation

- Accuracy and coverage
  - Tow-step analysis : precision 96.23%, recall 95.63%on ground truth
  - One-step analysis: precision 97.68%, recall 95.59% on ground truth

- Performance
  - Tow-step analysis: 0.016s/pair (94X faster)
  - One-step analysis: 1.5s/pair